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Preliminary Identification of Scenarios for the Waste Isolation Pilot Plant, Southeastern New Mexico

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PRELIMINARY IDENTIFICATION OF SCENARIOS FOR THE WASTE ISOLATION PILOT PLANT, SOUTHEASTERN NEW MEXICO*

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ABSTRACT

The Waste Isolation Pilot Plant is being evaluated as a location for the disposal of defense-generated transuranic waste. One of the criteria to be used to determine the suitability of the disposal system is compliance with the Containment Requirements established by the U.S. Environmental Protection Agency. One step in determining compliance is to identify the combinations of events and processes (scenarios) defining possible future states of the disposal system that may affect the escape of radionuclides from the repository and transport to the accessible environment.

A list of previously identified events and processes was adapted to a scenario-selection procedure that develops a comprehensive set of mutually exclusive scenarios through the use of a logic diagram. Four events resulted in the development of 16 scenarios. Preliminary analyses indicate that four scenarios result in no releases. Six scenarios consist of combinations of drilling into a waste-filled room, drilling into a room and an underlying brine reservoir, and emplacement of withdrawal wells downgradient from the repository. Six additional scenarios consist of these same six combinations with the addition of potash mining and the associated surface subsidence.

The 12 retained scenarios will be screened based on consequence and/or probability of occurrence. During the course of performance assessment, additional data and information will be used to revise and update these preliminary scenarios where appropriate.

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PREFACE

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PRELIMINARY IDENTIFICATION OF SCENARIOS FOR THE WASTE ISOLATION PILOT PLANT, SOUTHEASTERN NEW MEXICO*

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INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), which is located in southeastern New Mexico, is designed for the disposal of transuranic (TRU) wastes generated by the U.S. Department of Energy's (DOE) nuclear-based defense programs. This location is being evaluated for compliance with Subpart B of the U.S. Environmental Protection Agency's (EPA) *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule* [1] (the Standard). In order to determine compliance, a performance assessment of the disposal system must be carried out. An integral part of any performance assessment is the identification of the scenarios that are appropriate for the disposal system [2]. The purpose of this paper is to describe the methodology used by the WIPP project for identifying these scenarios and to describe the preliminary results from applying this methodology to the WIPP [3]. These preliminary scenarios are being used to guide the development of the modeling system for compliance calculations and to identify the data needs for performance assessment. As more data and information become available for the WIPP disposal system, and the development of the modeling system progresses, the results of the preliminary scenario development will be revised and updated where appropriate.

REGULATORY BASIS FOR SCENARIOS

Subpart B of the Standard contains the environmental requirements that apply to the disposal system after the waste has been emplaced and the repository/shaft system has been sealed. The Containment Requirements [4] state that cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall meet certain criteria. By implication, "all significant processes and events" includes all significant combinations of these processes and events. These combinations of processes and events generally are referred to as scenarios.

In addition to the Containment Requirements, the definition of performance assessment [5] refers to an analysis identifying the processes and events that might affect the disposal system. As in the Containment Requirements, this definition implies that the combinations of processes and events also must be considered.

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REQUIREMENTS OF A PROCEDURE FOR DEVELOPING SCENARIOS

Estimates of the cumulative releases of radionuclides from all significant processes and events in the performance assessment are to be incorporated into a probability distribution of cumulative releases to the extent possible [5]. Although the Standard does not mandate how this probability distribution is to be represented, Appendix B of Subpart B of the Standard is provided as "Guidance for Implementation of Subpart B." This appendix states that the EPA assumes the results of the performance assessment will be assembled into a complementary cumulative distribution function (CCDF).

The procedure for developing scenarios must produce a comprehensive set, so that no important scenarios are omitted. In addition, the scenarios must be mutually exclusive, so that the cumulative releases and the probability of occurrence can be combined in a CCDF.

DESCRIPTION OF SCENARIO-DEVELOPMENT PROCEDURE USED FOR THE WIPP

Much of the past work in identifying scenarios for nuclear-waste disposal systems was based on the use of event trees [6][7][8]. This type of analysis has been used to assess potential accidents at nuclear power plants [9]. Event trees were found not to be suitable for natural systems [10].

Because event trees cannot produce scenarios that adequately address the current formulation of the Standard, the WIPP project has adopted the scenario-development procedure developed by the Waste Management Systems Division of Sandia National Laboratories [11]. The application of this procedure to the WIPP will provide a final comprehensive set of mutually exclusive scenarios that are amenable to both consequence analysis and probability assignment.

In Cranwell and others [11], scenarios are defined as sets of naturally occurring and human-induced events and processes that represent realistic future changes to the repository, geologic, and hydrologic systems that may affect the escape and transport of radionuclides. The scenario-development procedure consists of five basic steps.

In the first step, the events and processes that may affect the escape of radionuclides from the waste panels and/or the transport of radionuclides to the accessible environment are identified. A panel of experts may be used to identify these events and processes, or an existing list of nonsite-specific events and processes compiled by panels of experts for previous studies can be used. Table 1 is the list from Cranwell and others [11].

The second step consists of classifying the events and processes in the comprehensive list into various categories as an aid in determining the completeness of the list. This step is organizational, and certain classification schemes can be beneficial to the modeling efforts.

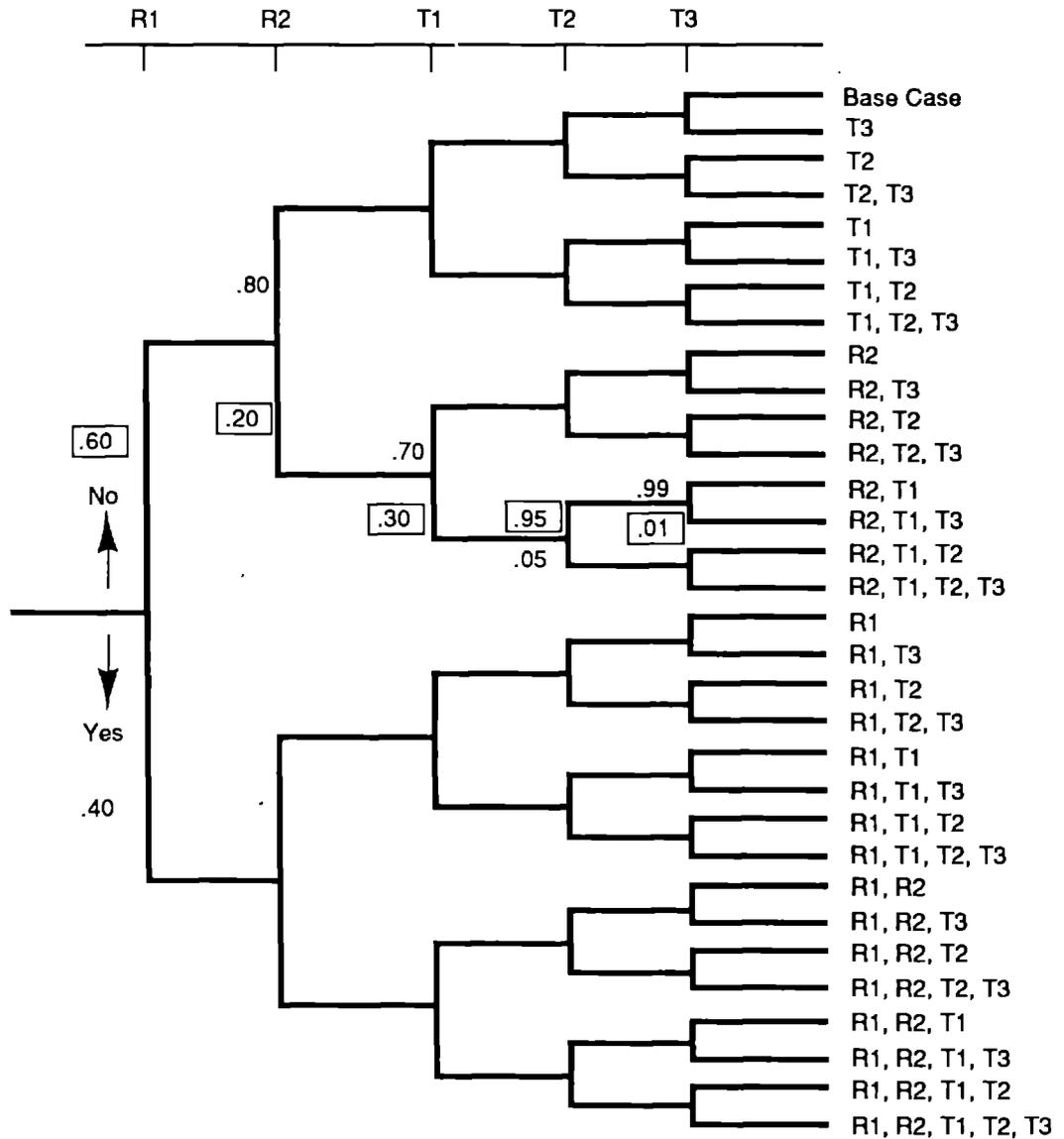
In the third step, the events and processes are screened to eliminate those that are not pertinent to the specific disposal system being investigated or do not contribute to the integrated release to the accessible environment. Three screening criteria can be used: physical reasonableness, probability of occurrence, and consequence. In addition to these screening criteria, Appendix B of the Standard limits the severity of human intrusion into the disposal system to exploratory drilling for resources.

TABLE 1. Potentially disruptive events and processes by category [after 11].

<u>Natural Events and Processes</u>	<u>Human-Induced Events and Processes</u>
<u>Celestial Bodies</u>	<u>Inadvertent Intrusions</u>
Meteorite Impact	Explosions
	Drilling
<u>Surficial Events and Processes</u>	Mining
Erosion/Sedimentation	Injection Wells
Glaciation	Withdrawal Wells
Pluvial Periods	
Sea-Level Variations	<u>Hydrologic Stresses</u>
Hurricanes	Irrigation
Seiches	Damming of Streams or Rivers
Tsunamis	
Regional Subsidence or Uplift (also applies to subsurface)	<u>Waste- and Repository-Induced Events and Processes</u>
Mass Wasting	
Flooding	Subsidence and Caving
<u>Subsurface Events and Processes</u>	Shaft and Borehole
Diapirism	Seal Degradation
Seismic Activity	Thermally Induced
Volcanic Activity	Stress/Fracturing in
Magmatic Activity	Host Rock
Formation of Dissolution Cavities	Excavation-Induced
Formation of Interconnected Fracture Systems	Stress/Fracturing in
Faulting	Host Rock

The fourth step in the procedure is the construction of scenarios by combining the events and the processes that survive the screening process. A logic diagram is used to construct the scenarios. Figure 1 is an example of a logic diagram for what were classified as hypothetical release and transport events and processes. No temporal relationship is implied by the sequence of events and processes across the top of the diagram or within the constructed scenarios. At each junction within the diagram, a yes/no decision is made as to whether the next event or process across the top of the diagram is added to the scenario. The pathway defined by "no" decisions at all of the branch points leads to the base-case scenario, which is the undisturbed performance of the disposal system. The time at which an event or process occurs relative to the other events and processes in the scenario is a variable for consequence modeling. This time of occurrence can be sampled during the uncertainty analysis.

Screening the scenarios is the last step in the procedure. In a strict mathematical approach, no scenarios can be eliminated from inclusion in the construction of a CCDF, because the summation of the probabilities of occurrence of all the scenarios in the logic diagram must be equal to 1. In a practical approach, some scenarios can be identified as having so little effect on the shape and location of the CCDF that consequence modeling of the scenarios is not necessary, although these scenarios should be considered when evaluating overall compliance of the disposal system to the Standard.



□ Indicates probability values needed to determine probability of scenario R2, T1, T3

Probability of R2, T1, T3 = $(.60)(.20)(.30)(.95)(.01) = 3.4 \times 10^{-4}$

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FIG. 1. Demonstration logic diagram for the construction of scenarios for hypothetical events and processes [after 11].

The criteria for screening scenarios to identify which scenarios do not require consequence modeling are physical reasonableness, probability of occurrence, and consequence. Physically incompatible events and processes can be virtually eliminated from scenario development by not allowing specific parameter values or specific locations of occurrence to define events and processes. Scenarios with probabilities of occurrence less than some value will have a minimal impact on the CCDF. As with the individual events and processes, the probability for scenarios was assumed to be less than one chance in 10,000 in 10,000 years. To determine the probabilities of the scenarios, the probability of occurrence and nonoccurrence of each event and process is assigned to the appropriate "yes" and "no" legs at each junction in the logic diagram (Figure 1).

The final screening criteria is consequence. At this stage of the procedure, consequence means release of radionuclides to the accessible environment within 10,000 years. In the screening process, calculations may be used to determine whether releases occur.

PRELIMINARY IMPLEMENTATION OF SCENARIO-SELECTION PROCEDURE

The steps of the Cranwell and others [11] scenario-selection procedure have not been rigorously applied to the scenario-development efforts for the WIPP performance assessment. Events and processes originally identified for use in event trees had to be adapted for use in a logic diagram.

Identified Events and Processes

As a starting point in the identification of events and processes, Hunter [12] used a list of events and processes that had been considered for studies in support of waste disposal sites in bedded salt in southeastern New Mexico and elsewhere [6][11][13][14]. A total of 24 events and processes were evaluated as to their pertinence to the WIPP. Because of the geologic stability of the region, tectonic, volcanic, and plutonic events and processes were eliminated as potentially disruptive events and processes. Hunter identified "...normal flow of ground water, climatic change, the drilling of exploratory boreholes, solution mining, seal performance, the effects of drilling into a brine reservoir beneath the repository, leaching of the solid waste, nuclear criticality, waste/rock interactions, and waste effects" [15]. Waste/rock interactions and waste effects were considered applicable to all scenarios. The remaining 14 events and processes were determined to be of no significance to the WIPP.

Evaluation and Adaptation of Events and Processes to Scenario-Selection Procedure

Some of the events and processes retained by Hunter [12] are expected to occur and therefore are part of the base-case scenario. These events and processes contribute to the undisturbed conditions that define the base-case scenario and are not appropriate for use in the logic diagram to develop additional scenarios.

Events and processes that are part of the base-case scenario are normal flow of ground water, climatic change, seal performance, and leaching of solid waste. Remaining events are modified from the drilling of exploratory boreholes to drilling into a waste-filled room or drift; from solution mining to potash mining outside the WIPP boundary; and from the effects of drilling into a brine pocket beneath the repository to drilling through a room or drift and into an underlying brine reservoir. The emplacement of withdrawal wells downgradient was added as an event, because these wells can provide alternate pathways for radionuclides to reach the accessible environment. Nuclear criticality is being evaluated separately, and if this process turns out to be feasible for the WIPP inventory and the disposal system, the scenario-development step in this procedure will be revised.

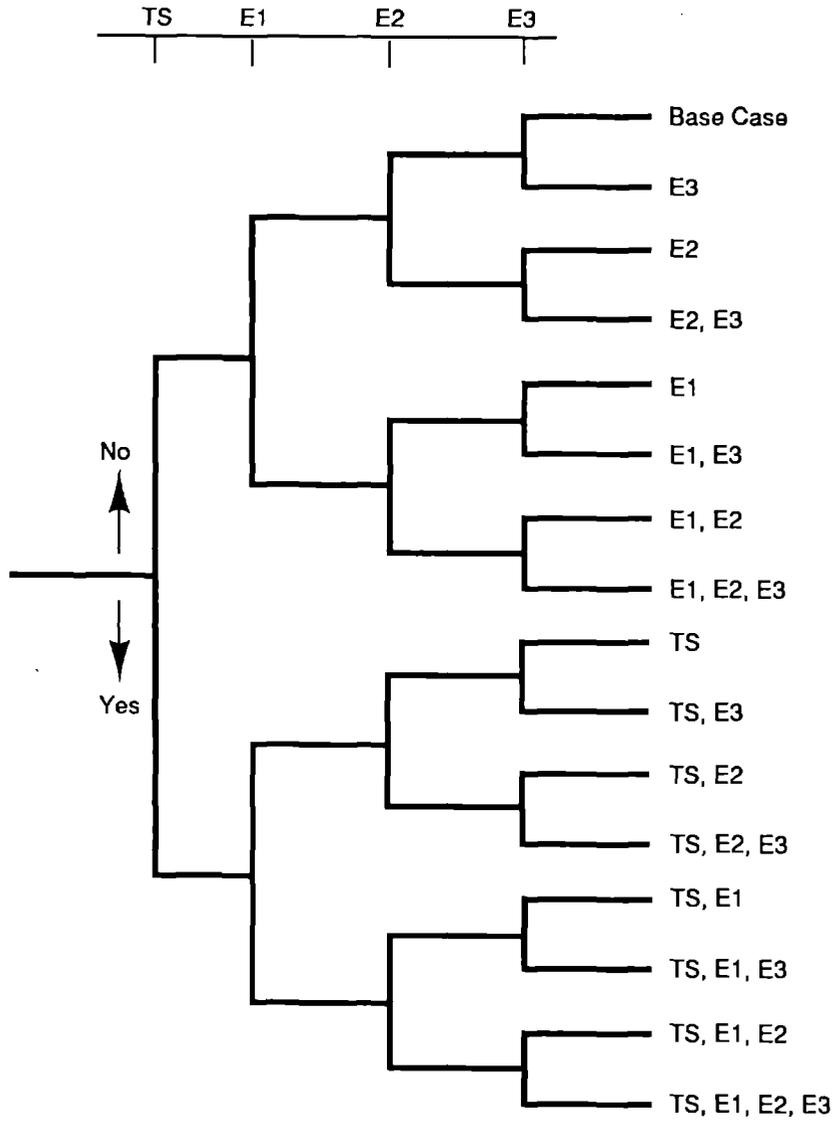
Development of Scenarios

The next step in the scenario-selection procedure is the development of scenarios by the use of a logic diagram. This diagram produces 2^n scenarios, where n is the number of events and processes incorporated in the diagram. With the four events retained for the WIPP, 16 scenarios are developed in the logic diagram (Figure 2). A separate task will determine the number of intrusions of each type of intrusion event. In addition, the location, the time of the intrusions, and the duration of pumping for withdrawal wells will be variables in the model(s) used for consequence analysis.

Two groups of scenarios can be delineated in the scenarios in Figure 2. One set consists of the various combinations of the intrusion events (E1 and E2) with the withdrawal well (E3), and the other set contains these same combinations with the addition of potash mining (TS).

STATUS OF SCENARIO SCREENING

Preliminary consequence modeling indicates that radionuclides only reach the accessible environment for those scenarios that include at least one event resulting in penetration of a room or drift. Because of these results, the base-case scenario and scenarios E3, TS, and TSE3 can be eliminated from further consideration. The assumptions made for these analyses will be reviewed and revised as needed for the final performance assessment. An additional effort to determine the probabilities of the events in the scenarios is in progress.



TS - Potash Mining Outside the WIPP Boundary
 E1 - Drilling Through Room or Drift and Into Brine Reservoir
 E2 - Drilling into a Room or Drift
 E3 - Emplacement of Withdrawal Well Downgradient From Repository

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FIG. 2. Preliminary scenarios developed with a logic diagram for WIPP disposal system [3].

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